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Doc.-Title:	**Technical Note TN 4.1** **ADM-Aeolus Airborne Campaign 1/2/3** **AC01/AC02/AC03 Implementation Plan**
Number of pages:	26 pages
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0.1 Document Change Log

Issue.	Date	New pages	Modified pages (after introducing new pages)	Observations	Name
dr.	06.11.2007	--	--	draft prepared	Reitebuch
V1.0	13.11.2007			first version prepared with comments from Christian Lemmerz and Anne-Grete Straume	Reitebuch
V2.0	31.10.2008	new chapter 2.3, 5 and 6	4, 6, 9	revised version prepared to include AC02 implementation; main changes are highlighted in blue	Reitebuch
V2.1	14.11.2008		9	Tab 1.coordinates Cabauw corrected, comments Alain Dabas implemented, changes are highlighted in red	Reitebuch
V3.0	28.05.2009	new chapter 7 and 8; pages 19-26	updated Fig. 3 modified pages 1-5, and 7	revised version with AC03 implementa-tion, changes are highlighted in blue	Reitebuch
V3.1	15.07.2009		p. 5, 7, 20, 22-25	revised version with comments from ESA implemented, changes to V3.0 in blue	Reitebuch

0.2 Table of Contents

1 Introduction and Purpose of Document

This Technical Note TN 4.1 defines the implementation of the first ADM-Aeolus Airborne Campaign AC01 and AC02. It covers tasks of workpackage WP 4100 of the study contract “Planning and execution of Aeolus Campaigns” by DLR from 5 April 2004, based on the Statement of Work from ESA SW-ESA-AD-015, Issue 01a (ESA 2004, DLR 2004). The TN was prepared by Oliver Reitebuch (DLR).

The AC01/AC02 Implementation plan is based on the campaign objectives defined in TN 1.2 (AE.TN.DLR.A2D.TN12.010305), the implementation plan for the ground campaigns defined in TN 3.1 (AE.TN.DLR.A2D.TN31.080906), the experience with operating the ALADIN Airborne Demonstrator A2D during two ground campaigns in Lindenberg, and the experience gained during two test flight campaigns in October 2005 and April 2007 and the first airborne campaign AC01 in November 2007.

The TN was updated to V2.0 and includes the objectives of the second airborne campaign AC02 in chapter 2.3, the instrumentation in chapter 5, and the implementation of AC02 in chapter 6.

The TN was updated to V3.0 and includes the objectives of the third airborne campaign AC03 in chapter 2.4, the instrumentation in chapter 7, and the implementation of AC03 in chapter 8. A revised version V3.1 was prepared with implemented changes according to comments from ESA.

2 Objectives of the first ADM-Aeolus airborne campaign AC01

2.1 Recall of general objectives

The main objectives of the ADM-Aeolus campaigns are

- Validation of the predicted instrument radiometric and wind measurement performance.
- Establishing a dataset of atmospheric measurements obtained with an ALADIN type instrument to improve algorithm development for L1B (uncorrected horizontal line-of-sight HLOS wind speed), L2A (aerosol and cloud products) und L2B products (corrected HLOS wind speed).

The ADM-Aeolus campaigns should address the following questions:

1. a) Is the actual instrument radiometric performance (number of detected photons) in the expected range?

   b) Is the actual instrument wind observation performance (accuracy and bias of wind observation) within the expected range?
2. What is the influence of real homogenous atmospheres on the instrument performance including operational L1b algorithms?
3. Do temperature and pressure corrective schemes for Rayleigh winds operate well?
4. What is the influence of real atmospheres under mostly inhomogenous conditions (clouds, wind shear, and aerosol) on the instrument performance including operational L1b algorithms?
5. Can an improvement be achieved by other algorithm implementations and Quality-Control-methods? Have further correction schemes to be implemented in the processing?
6. What is the performance of the calibration using the laser pulse as internal reference? What are the implications of the Mie and Rayleigh response calibration modes, which rely on atmospheric targets and ground return?
7. What is the effect of the atmosphere on the ground return bin? Does the proposed detection scheme for the ground return work under different conditions?
8. What is the detectability and strength of the return from water under 0° (specular reflection) and 35°? What is the detectability and strength of the ground return over land, e.g. ice, snow surfaces or des-serts?
9. What is the effect of real atmospheric conditions including inhomogeneity on L2B processing?
10. What L2A products (aerosol, cloud) could be derived under different atmospheric conditions?
11. What is the variability of geophysical parameters (atmospheric backscatter, extinction, ground return strength, clouds) during different conditions and over different locations?

2.2 Objectives of first airborne campaign AC01

The objectives for the first airborne campaign are as follow:

- Functional test of A2D and 2-µm wind lidar operation
- Obtain dataset for ground return detection and zero-wind calibration algorithm over different surfaces (sea, land, steep/flat orography)
- Calibration strategy during airborne campaigns
- Radiometric performance with downward looking geometry
- Stability of alignment (and thus wind retrieval) in the aircraft
- Establish strategy for intercomparison satellite/airborne LOS to ground-based wind-vector observations: observational geometry, temporal and spatial sampling

2.3 Objectives of second airborne campaign AC02

The objectives of the first airborne campaign AC01 were partly achieved. Thus the objectives of the second airborne campaign include the objectives of AC01, which were not fully covered, and reflect mainly the experience gained during AC01 and the characterization of laser and receiver pressure dependency.

Thus the objectives for AC02 are:

- Test optimized A2D operation wrt
    - automatic co-alignment loop and stability of alignment
    - compensation of pressure dependency by a different Rayleigh spectrometer temperature compared to ground operation
    - monitoring of absolute laser frequency in flight with calibrated wavemeter
- Obtain dataset over sea surface, especially with high nadir angles, e.g. 30° and 37.5° to consolidate new sea surface reflectance model
- Performance of in-flight response calibration
- Wind intercomparison with ground windprofilers

2.4 Objectives of third airborne campaign AC03

The objectives of the second airborne campaign AC02 were partly achieved. Thus the objectives of the third airborne campaign include the objectives of AC02, which were not fully covered, in addition to new objectives for AC03.

The objectives for AC03 are in order of priority:

- Test optimized A2D operation wrt expected enhanced signal levels on UV camera for co-alignment
- Performance of in-flight response calibrations with nadir pointing over ice and snow
- Performance of nadir pointing and off-nadir (nominal) pointing measurements over land to analyze systematic errors on wind retrieval and zero-wind calibration scheme
- Observations of high wind speeds in combination with high vertical and possibly horizontal wind shear, e.g. within the jet stream region
- Obtain dataset over sea surface reflectance especially for high sea surface winds and anisotropic reflectance with upwind/downwind and crosswind situation
- Observations of marine air-masses with low aerosol content
- Provide test data sets for operational L1B, L2A and L2B processors
- Obtain dataset with varying albedo in nadir and off-nadir (nominal) pointing modes over land and over broken clouds
- Performance of nominal pointing observations over land and varying the range of the ground-return by either rolling the aircraft or flying over land with slowly increasing elevation.
- Observation of cloudiness and measurement coverage (Mie/Rayleigh) over centre of developing low pressure systems

3 Instrumentation during AC01

3.1 Payload of the DLR Falcon aircraft

The payload of the DLR Falcon aircraft will consist of the A2D and the 2-µm Doppler wind lidar (Fig. 1), which will be integrated into the Falcon aircraft for the first time in this combination. 2 seats are available on the Falcon aircraft, which will be shared among the operators for the A2D and 2-µm lidar.

The "Unobjectionable Form" ("Unbedenklichkeitserklärung") from the A2D Laser Test Flights (April 2007) is valid until October 26, 2007. As A2D flights are foreseen in November 2007, this form has to be re-issued. In addition the mounting of the 2-µm electronic rack had to be mechanically adapted and a stress analysis was performed and reviewed by DLR certification engineers. The required documentation to obtain a "Unobjectionable Form" were prepared and sent to the approval authority ("Musterprüfleitstelle"). A final approval is expected from that authority after a ground test related to EMC was performed inside the aircraft after integration of the A2D and 2-µm wind lidar.

The following improvements and modifications on the A2D have been performed since the end of the second ground campaign (August 2007):

- the refractive index-matching fluid inside the Electro-Optical-Modulator EOM of the receiver front optics was refilled; a visual inspection of the fluid level has been performed, but the signal transmission has not been verified with atmospheric signals. It was not necessary to dismount the EOM for this procedure, thus no issues with misalignment are expected.
- the Reference Laser Head RLH was modified by Innolight in order to achieve a different temperature and thus frequency for the reference laser in order to match the A2D power laser oscillator gain profile. This was verified at DLR with Optical Spectrum Analyser measurements. In addition the diodes from the seed laser were exchanged, because of degradation, and the heterodyne path of the seed/reference laser was realigned to solve the problems with the PLL locking range. It was verified at DLR, that the problems with the PLL locking were solved and the RLH can be tuned over a frequency range of about 11 GHz without mode-hopping.
- the light leakage of the OBA was identified at the connector bracket and the connector bracket were covered with additional tape.
- the settings of the Ramp-Fire electronic were tested in order to achieve a pre-trigger time of 60 µs before laser pulse emission. This was achieved by a longer time for the piezo ramp, and by using 3 interference peaks from the LPO laser cavity. A trigger electronic to provide the correct trigger scheme for the DEU was developed and tested.
- the A2D power laser head IR path and UV path was re-aligned and the UV beam expander was exchanged by a type with higher magnification (from 4 to 5); thus the beam diameter was increased and the divergence decreased. The laser energy was determined to be higher than 60 mJ and a beam divergence measurement with a 2-m lens was performed. Preliminary analyses show M^2 values of around 1.2 (before 1.8) and a laser divergence of below 100 µrad (± 3 σ).
- a small damage on the Falcon aircraft window of 2-3 mm was detected at the begin of August. The aircraft window was polished by an external company in order to remove the damage. A pressure test for certification purpose was performed at DLR with success and the documentation prepared.

The A2D and the 2-µm lidar will be pointing in the same line-of-sight LOS direction to the right side of the aircraft (in flight direction) with a nadir angle of 20°. The instruments are mounted as follow

- the A2D aircraft frame is mounted with a pitch angle of -6° (pointing to the back) along the aircraft axis; the telescope is mounted such that it points towards the right with an roll angle of 20°
- the 2-µm is mounted with a pitch angle of -2° (pointing to the back) along the aircraft axis. It is equipped with a double-wedge scanner, which allows to point towards -6° and a roll angle of 20°. Small offsets in the order of 0.1° of the 2-µm pointing direction will be determined in flight.

The nominal operation of the 2-µm lidar will be the measurement of the LOS wind. Some conical step-stare scans will be performed in order to measure the horizontal wind vector during flight.

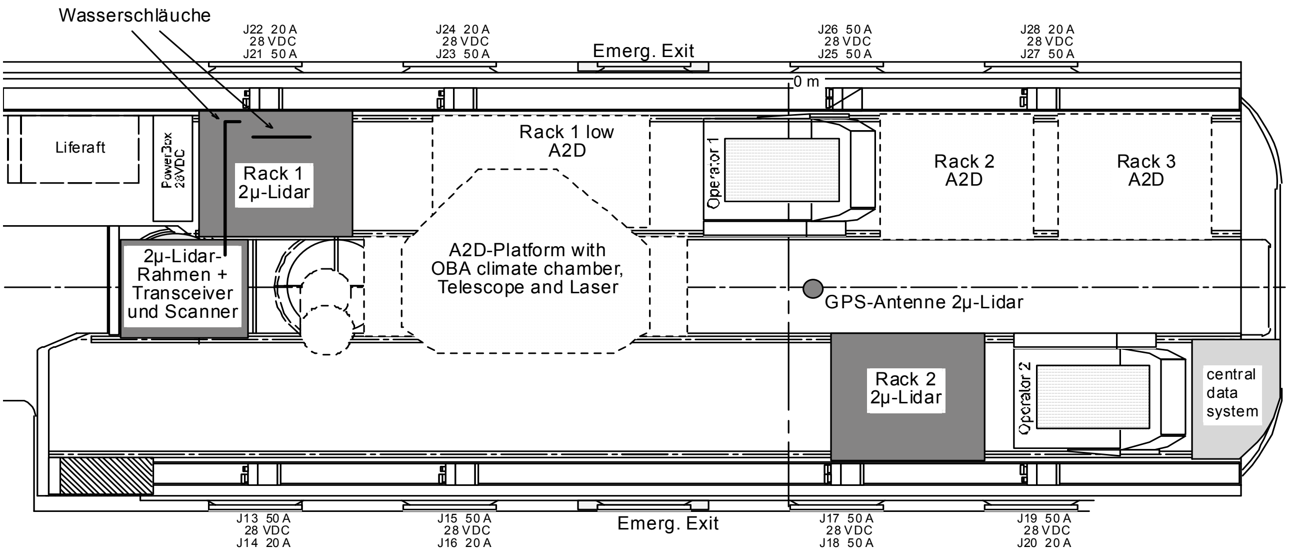

Fig. 1: Cabin layout of the Falcon aircraft with the A2D and the 2-µm lidar.

The vertical sampling of the A2D will be set such, that at least 2 range gates are below the ground of < 0 m ASL, and the first 3 km of the atmosphere are sampled with the highest possible resolution of 315 m (2.1 µs). The internal reference signal will be set in range gate 4, thus leaving a total of 20 range gates for atmospheric signals. Assuming a flight altitude of 10 km, which corresponds to a range of 10.6 km at a nadir angle of 20 °, the vertical sampling could set as:

- 1 range gate   4.2 µs = 630 m from range of   -1.4 km to -0.8 km (Layer 24)
- 11 range gates   2.1 µs = 315 m from range of   -0.8 km to 2.7 km (Layer 13-23)
- 2 range gates   4.2 µs = 630 m from range of   2.7 km to 4.0 km (Layer 11-12)
- 5 range gates   8.4 µs = 1.26 km from range of   4.0 km to 10.3 km (Layer 6-10)
- 1 range gate   2.1 µs = 315 m from range of   10.3 km to 10.6 km (Layer 5)

By rolling the aircraft with 20 °, a nadir angle of 0 ° for the A2D LOS can be achieved. This corresponds to a range of 10 km, and the range gates will be shifted towards lower ranges by 0.6 km, resulting in more ranges below ground. By rolling the aircraft with -18°, a nadir angle of 38° for the A2D LOS can be achieved, which corresponds to the satellite LOS nadir angle. Thus the range increases to 12.6 km, which corresponds to a shift of 2 km of all range gates. This has to be compensated by a different vertical sampling scheme, e.g. by change of 2 range gates from 8.4 µs to 16.8 µs, which corresponds to an increase in range of 2.5 km. Both rolling manoeuvres are foreseen to be performed over sea.

The 2-µm wind lidar will be operated in a fixed LOS pointing in the same direction as the A2D. The vertical resolution of the 2-µm is 100 m (for more details see AE.TN.DLR.A2D.TN31.080906).The laser pulse repetition frequency is 500 Hz and the signals from the atmosphere are sampled for every single laser shot and thus available every 2 ms. The signals will be averaged during post-processing stage within 1 s to obtain 1 LOS wind speed profile. Thus the horizontal resolution of the 2-µm LOS wind speed profile will be 200 m, assuming an aircraft ground speed of 200 m/s. It is possible to operate the 2-µm wind lidar in a conical scanning mode to obtain the horizontal wind vector. One scan is performed within about 20 s and thus the horizontal resolution of the wind vector profiles is about 4 km for 200 m/s aircraft ground speed. The accuracy of the horizontal wind speed is between 0.5 – 0.75 m/s, assessed during earlier airborne experiments by comparison with nearby dropsonde winds.

3.2 Instrumentation on the ground

It is foreseen to fly over Lindenberg and the sites of Bayreuth, Ziegendorf and Nordholz, which are equipped with the the same type of tropospheric 482 MHz windprofilers than in Lindenberg.

The following instrumentation will be operated at Lindenberg:

- 482 MHz windprofiler measuring vertical profiles of the horizontal wind vector, vertical wind speed and virtual temperature with a Doppler Beam Swing DBS technique during 30 minutes.
- the Raman lidar RAMSES operating at 355 nm during night hours (about 17:30 LT in November)
- 4 operational radiosondes at 0, 6, 12, 18 UTC for profiles of temperature, horizontal wind vector, relative humidity and pressure

No other ground instrumentation is installed at the sites in Bayreuth, Ziegendorf and Nordholz. The closest radiosondes to these sites are in the order of 100-200 km distance. It is foreseen to fly over the aerosol Raman lidar of IfT in Leipzig operating at 355 nm, 532 nm (and possibly 1064 nm, http://lidar.tropos.de/instrumente/ramanlidar.html).

The coordinates of the ground sites for AC01 from the network of aerosol lidars EARLINET (Fig. 2), windprofilers CWINDE (Fig. 3), and radiosondes (Fig. 4) are summarized in Table 1.

Site	Location	Instruments	next radiosonde
Lindenberg, North Germany	52.21 °N (52° 12.6') 14.13 °E (14° 7,8') 107 m	482 MHz windprofiler (RASS), Raman lidar RAMSES, radiosonde	directly on site
Ziegendorf, North-Germany	53.31 °N (53° 18.6') 11.84 °E (11° 50,4') 55 m ASL	482 MHz windprofiler (RASS)	Greifswald (135 km), Bergen (140 km)
Nordholz, North-Germany	53.78 °N (53° 46.8') 08.67 ° E (8° 40.2') 18 m ASL	482 MHz windprofiler (RASS)	Schleswig (100 km), Emden (183 km)
Bayreuth, South-Germany	49.98 °N (49° 58.8') 11.68 °E (11° 40,8') 514 m ASL	482 MHz windprofiler (RASS)	Kuemmersbruck (63 km)
Leipzig, North-Germany	51.375 °N (51° 22.5') 12.446 °E (12° 26.8') 120 m ASL	Aerosol Raman lidar MARTHA at 355 nm, 532 nm, (1064 nm)	Lindenberg (151 km)
Cabauw, Netherlands	51.97 °N (51° 58.2') 4.927 °E (4° 55.6') -0.5 m ASL	1290 MHz windprofiler, RASS,	de Bilt (30 km)
Bilthoven, Netherlands	52.121 °N (52° 7.234') 5.192 °E (5 °11.510')	RAMAN lidar CAELI 355 nm, 532 nm, 1064 nm	de Bilt (3 km)

Tab. 1: Coordinates of ground sites for AC01 from CWINDE network and EARLINET network

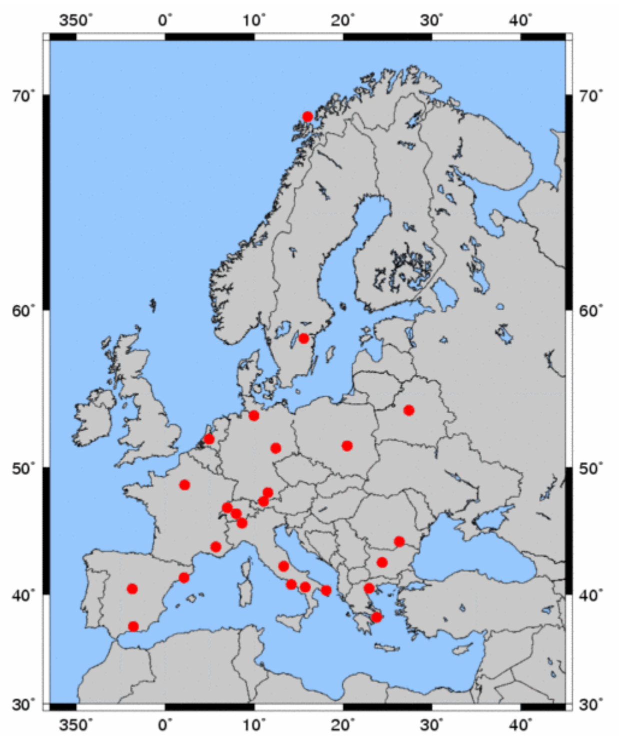

Fig. 2: EARLINET aerosol lidar network (http://www.earlinetasos.org/)

Fig. 3: CWINDE Profiler Network 2009 (http://www.meto.gov.uk/research/interproj/cwinde/)

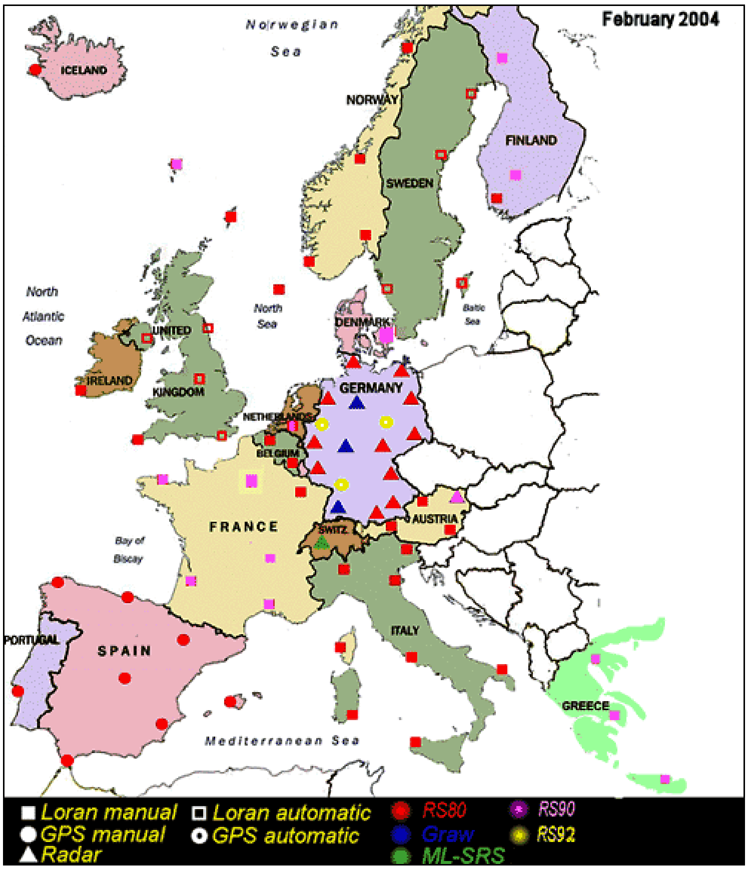

Fig. 4: Radiosonde Network (http://www.met-office.gov.uk/research/interproj/radiosonde/index.html)

4 Implementation AC01

The aircraft will be based at DLR Oberpfaffenhofen. Integration of the A2D and 2-μm will start on November 8. The Falcon aircraft is available until November 30, but it is planned to finish the campaign by November 23. A ground test for EMC purpose is needed, because of the integration of the A2D and the 2-μm lidar, inside the Falcon aircraft for the first time. This test is foreseen for November 12. Thus the first flight is foreseen for November 13.

Flights can be performed during weekdays and during the weekend of November 17/18, if the weather allows. Weekend operation has to be decided on Thursday. Flight 1 has to be performed first; the order of flight 2, 3 and 4 can be exchanged. A flight altitude of 10 km (FL300) is foreseen for all flights. Each flight should have duration of about 4 hours. A total of 4-5 flights are foreseen.

The flights over sea should be preferably performed during calm wind conditions. The sea surface reflectance is strongly dependent on wind speed due to white cap reflections. Reflectivity is enhanced for higher wind speeds. In order to study the reflectance under different incidence angles (0°, 20°, 37,.6°), it is preferred to start with simple surface reflectance conditions for wind speeds below about 6 m/s.

4.1 Flight 1

Objective: Test A2D operation in the aircraft, test A2D laser triggering and frequency stability during flight, verify and possibly improve atmospheric path alignment

Weather: no clouds, or broken clouds during some parts of the flight needed

Flight Level: 10 km (FL300)

Flight path: no specific flight path requested, but some parts of the flight should have no/low cloud cover

Duration: up to 4 hours

Remarks: No operation of the 2-μm lidar, because no seat will be available for 2-μm operator, and 2-μm data acquisition will be used for A2D heterodyne measurements

4.2 Flight 2

Objective: Ground return flight

Weather: no clouds, or broken clouds during most parts of the flight needed; ground visibility, low surface wind speeds favorable, calm wind conditions over sea

Flight Level: 10 km (FL300)

Duration: up to 4 hours

Flight path:

1) Flight above Alps from North to South with possible overpass of Garda lake (3.6 km to the East off the N-S axis of the lake)

2) Flights above Mediterranean Sea:

   2.1) straight leg of 100 km,

   2.2) 1-3 circles with roll angle of 20° (right curve) for about 5 minutes per circle

   2.3) 1-3 circles with roll angle of -18° (left curve) for about 5 minutes per circle,

   2.4) straight leg of 100 km

3) Flight above Alps South-North with possible overpass of Garda lake (3.6 km to the West off the N-S axis of the lake)

4) Flight along Alps West to East from Bodensee to Chiemsee (or vice versa)

Remarks: Flight Level of 10 km and 20° off nadir angle results in separation of aircraft ground track to measurement ground track of 3.6 km

4.3 Flight 3

Objective: Study validation strategy

Weather: no clouds, or broken clouds during most parts of the flight needed, calm wind conditions over sea

Flight Level: 10 km (FL300)

Duration: up to 4 hours; flight will be performed during darkness; take-off in Oberpfaffenhofen at 17:30 (LT) and landing latest at 22:00 (LT)

Flight path:

1) Flight above windprofiler site Bayreuth (49.98°N, 11.68°E) with straight leg of 100 km centered at windprofiler

2) Flight above aerosol lidar site in Leipzig (51.375 °N, 12.446 °E) with straight leg of 100 km centered at Leipzig

3) Flight above windprofiler site Lindenberg (52.21°N, 14.13°E) with rectangular box of 100 km centered at Lindenberg (18 UTC = 19 LT radiosonde at Lindenberg)

4) Flight above windprofiler site Ziegendorf (53.31°N, 11.84°E) or Nordholz (53.78°N, 8.67°E) with straight leg of 100 km centered at windprofiler

5) Flight above Baltic Sea or North Sea, with possible circles of 20° (right curve) and -18° (left curve) roll angle

6) Flight above windprofiler site Ziegendorf/Nordholz

7) Flight above windproifler site Lindenberg

8) Flight above aerosol lidar site Leipzig

9) Flight above windprofiler site Bayreuth

Remarks: Flight Level of 10 km and 20° off nadir angle results in separation of aircraft ground track to measurement ground track of 3.6 km; permission for landing later then 21 LT has to be obtained.

4.4 Flight 4

Flight 4 is same as Flight 3 but during day hours

4.5 Flight 5

A possible 5th flight will be performed to repeat one of the flight patterns during flight 2, 3 or 4.

5 Instrumentation during AC02

5.1 Payload of the DLR Falcon aircraft

The payload of the DLR Falcon aircraft will consist of the A2D and the 2-µm Doppler wind lidar DWL (Fig. 1) as for AC01. It was applied for the "Unobjectionable Form" ("Unbedenklichkeitserklärung") for airworthiness certification and it has been already reissued by the approval authority ("Musterprüfleitstelle"). A final approval is expected from that authority after a ground test related to EMC is performed inside the aircraft after integration of the A2D and 2-µm DWL.

The following improvements and modifications on the A2D have been performed since the first airborne campaign in November 2007:

- pressure dependency of Mie and Rayleigh spectrometer, laser and wavemeter was characterised; the Rayleigh spectrometer will be operated with a 2.2 K lower temperature than on ground to compensate for a pressure change of 100 hPa in the cabin
- automatic co-alignment loop was implemented and tested; this will compensate alignment drifts and allow a much improved reproducibility in alignment; a major improvement in stability of the instrument alignment and the wind retrieval is expected
- a new wavemeter with autocalibration mode was procured; the wavemeter will be operated during flight, a trigger for A2D burst mode was implemented for wavemeter data acquisition
- the piezo of the laser master oscillator was replaced with a new one after damage and the mechanical interface to the mount was strengthened; this improved the long-term stability of the cavity control loop, which results in less changes of the cavity-control parameters by the operator
- the damaged telescope ocular lens was replaced
- damaged optics inside the laser were replaced; laser output energy is around 60 mJ and divergence below 100 µrad (±3σ) as during AC01

The 2-µm DWL was re-aligned during a campaign in Japan in September 2008 and was operated on more than 20 flights with good performance.

The A2D and the 2-µm will be mounted inside the aircraft cabin as during AC01 and pointing with their LOS perpendicular to the aircraft axis with an angle of 20° off nadir. The nominal operation of the 2-µm lidar will be the measurement of the LOS wind. Some conical step-stare scans will be performed in order to measure the horizontal wind vector during flight. Different off-nadir angles of both instruments, e.g. 0°, 20°, 30°, and 37.5° will be achieved by rolling the aircraft while flying curves. The vertical sampling of the A2D will be similar as during AC01, adapting for a higher range from aircraft to ground, when operating with 37.5° off nadir angles.

5.2 Instrumentation on the ground

It is foreseen to fly over the same ground sites as during AC01, depending on weather. This would be the windprofiler sites Lindenberg, Bayreuth, Ziegendorf and possible Nordholz, and the Earlinet sites Leipzig and Cabauw.

In addition to the ground sites of chapter 3.2 it is considered to fly over the Cabauw Experimental Site for Atmospheric Research CESAR, Netherlands (http://www.cesar-observatory.nl/), which is equipped with a 1290 MHz boundary layer windprofiler. Radiosondes are launched close to Cabauw at KNMI in de Bilt at 0 and 12 UTC. Additional radiosondes around 18 UTC could be launched from KNMI on request. The multiwavelength RAMAN lidar CAELI operating at 355 nm, 532 nm and 1064 nm is placed at RIVM, Bilthoven. All sites are within about 30 km distance.

6 Implementation AC02

The aircraft will be based at DLR Oberpfaffenhofen. Integration of the A2D and 2-µm will start on November 24. The Falcon aircraft is available until December 10 and flights are possible until December 7 including the weekends of November 29/30 and December 6/7. Integration and EMC testing is foreseen for November 24 and 25. Before the test flight an alignment of transmit-receive path is needed with atmospheric signal. This requires taking out the Falcon aircraft off the hangar and pointing the laser towards the atmosphere with a ground mirror for some hours. Preferably clear sky or few clouds without precipitation is needed for that. Thus the test flight could be earliest on November 26 in the afternoon after performing the atmospheric alignment. In case of unfavorable weather conditions for atmospheric alignment the test flight will be delayed. Two operators will fly on the Falcon during AC02, which will be able to operate both the A2D and the 2-µm DWL.

A total of 4 flights including 1 test flight are foreseen. In addition a 5th flight could be performed in case one of the earlier flights failed. Weekend operation has to be decided on Thursday. The test flight should have duration of about 3 hours, while the other flights have a duration of about 4 hours. Thus a total of about 15-20 flight hours will be obtained.

It is foreseen to operate the aircraft air conditioning system such, that the aircraft cabin pressure variation is minimal with a variation of +-2 hPa even when changing the flight level (tbc). During AC01 cabin pressure changes of up to 10 hPa were observed, when the flight level was changed. The pressure and temperature in the cabin will be monitored with sensors.

During AC01 the A2D laser and its cooling system reached thermal stability after about 1 hour in flight. The laser cooling system is switched off, when the aircraft is on ground and can be switched on, when a flight level of about 5 km is reached. Then the outside temperature is sufficiently low that a sufficient heat removal to the outside of the cabin is obtained. It is foreseen to operate a ground cooler close to the aircraft on-ground, while the aircraft is outside of the hangar, e.g. for taking fuel. This will maximize the time for cooling the laser system on-ground, and it is expected that the time needed in-flight for thermal stabilization is reduced (tbc).

During the first flight or an additional flight it is planned to perform an atmospheric response calibration with nadir pointing over land by rolling the aircraft with 20°. The in-flight response calibration in nadir pointing geometry will be compared to zenith pointing, atmospheric response calibrations performed at DLR in October/November from the container and atmospheric response calibrations performed from the aircraft on-ground. Depending on the comparison, it will be decided which calibration (in-flight or from ground) will be used for wind retrieval for the airborne observations. As the in-flight response calibration is used for off-line wind-retrieval and not needed for correct instrument operation it can be either performed during first flight or during a separate flight.

6.1 Flight 1

Objective: Functional Test Flight: test A2D operation in the aircraft, especially automatic co-alignment loop; verify atmospheric path alignment, verify Rayleigh spectrometer temperature setting to compensate for pressure change, test 2-µm DWL operation, Perform In-flight response calibration

Weather: clear sky, or broken clouds during some parts of the flight needed

Flight Level: 10-11 km (FL350)

Flight path: no specific flight path requested, but some parts of the flight should have no/low cloud cover

1) Flight along straight legs of minimum 100 km / 10 minutes for about 2 hours

2) Circle flights with roll angle of 20° (right curve), resulting in about 3° nadir angle, for about 30 minutes over land (response calibration)

3) Repeat 2, if possible

Duration: 3 hours

Remarks: circle flight of 30 minutes requested over land, could be performed in a Temporary Reserved Airspace TRA; part 2 of this flight could be performed in a separate 5th flight. TRA´s in Northern Germany were identified to be large enough to fly the requested circles.

6.2 Flight 2

Objective: Sea surface flight

Weather: clear sky needed over sea, preferably performed during high wind conditions to complement dataset of AC01, which was mainly during low wind conditions

Flight Level: 10-11 km (FL350) for transfer and 7-8 km (FL 250) over sea for circles

Duration: up to 4.5 hours

Flight path:

1) Flight north of the Alps for about 45-60 minutes until stable laser operation is obtained

2) Flight towards Mediterranean Sea as during AC01 (e.g. Nov 17 to Spain, or November 28 towards Adriatic Sea), possibly overpass of Garda lake (3.6 km to the East of the N-S axis of the lake)

3) Flights above sea on lower flight level, e.g. 7-8 km (FL 250)

3.1) straight leg of 100 km

3.3) 2 circles with roll angle of 10° (right curve) resulting in about 10° nadir angle

3.2) 2 circles with roll angle of 20° (right curve), resulting in about 3° nadir angle

3.2) 2 circles with roll angle of -18° (left curve), resulting in about 38° nadir angle

3.3) 2 circles with roll angle of -10° (left curve) resulting in about 30° nadir angle

3.4) straight leg of 100 km

3) Flight above Alps South-North with possible overpass of Garda lake (3.6 km to the West off the N-S axis of the lake)

Remarks: Flight Level of 10 km and 20° off nadir angle results in separation of aircraft ground track to measurement ground track of 3.6 km

6.3 Flight 3

Objective: Wind intercomparison flight Ziegendorf-Lindenberg-Leipzig-Bayreuth

Weather: no clouds, or broken clouds during most parts of the flight needed

Flight Level: 10-11 km (FL300) or lower; not below 8 km (FL 270)

Duration: up to 4.5 hours; flight will be performed during darkness; take-off in Oberpfaffenhofen at 16:30 (LT) and landing latest at 21:00 (LT)

Flight path (similar to ACO1 Nov 15 and Nov 19)

1) Flight for about 30 minutes North of the Alps to allow laser stabilisation and then towards North Germany

2) Flight above windprofiler site Ziegendorf (53.31°N, 11.84°E) with straight leg of 100 km centered at windprofiler

3) Flight above Baltic Sea, with possible 1 circle of 20° (right curve), -18° (left curve), and -10° (left curve) roll angle

4) Flight above windprofiler site Lindenberg (52.21°N, 14.13°E) with rectangular box of 100 km centered at Lindenberg and oriented perpendicular to predicted wind direction

5) Flight above aerosol lidar site in Leipzig (51.375 °N, 12.446 °E) with straight leg of 100 km centered at Leipzig

6) Flight above windprofiler site Bayreuth (49.98°N, 11.68°E) with straight leg of 100 km centered at windprofiler and back to Oberpfaffenhofen

Remarks: The flight tracks around Lindenberg should be oriented such that 1 leg is perpendicular to predicted wind direction from day before; radiosonde launch in Lindenberg is around 18 UTC = 19 LT

6.4 Flight 4

Objective: Wind intercomparison flight Cabauw-Nordholz-Ziegendorf-Lindenberg-Leipzig-Bayreuth

Weather: no clouds, or broken clouds during most parts of the flight needed

Flight Level: 10-11 km (FL350) or lower, not below 8 km (FL 270)

Duration: up to 4.5 hours; flight will be performed during darkness; take-off in Oberpfaffenhofen at 16:30 (LT) and landing latest at 21:00 (LT)

Flight path

1) Flight towards North Sea

2) Flight above North Sea, with possible 1 circle of 20° (right curve), -18° (left curve), and -10° (left curve) roll angle

3) Flight above windprofiler site Cabauw (51.97 °N, 4.927 °E) and lidar site Bilthoven (52.121 °N, 5.192 °E) with straight leg of 100 km centered at Cabauw-Bilthoven line

2) Flight above windprofiler site Nordholz (53.78°N, 08.67°E) with straight leg of 100 km centered at windprofiler

2) Flight above windprofiler site Ziegendorf (53.31°N, 11.84°E) with straight leg of 100 km centered at windprofiler

4) Flight above windprofiler site Lindenberg (52.21°N, 14.13°E) with straight leg of 100 km centered at Lindenberg and oriented perpendicular to predicted wind direction

5) Flight above aerosol lidar site in Leipzig (51.375 °N, 12.446 °E) with straight leg of 100 km centered at Leipzig

6) Flight above windprofiler site Bayreuth (49.98°N, 11.68°E) with straight leg of 100 km centered at windprofiler and back to Oberpfaffenhofen

Remarks: The flight tracks around Lindenberg should be oriented such that leg is perpendicular to predicted wind direction from day before; radiosonde in Lindenberg is around 18 UTC = 19 LT

6.5 Flight 5

A possible 5th flight will be performed to repeat one of the flight patterns, e.g. circle flight in TRA for about 30 minutes – 1 hour to repeat in-flight calibration.

7 Instrumentation during AC03

7.1 Payload of the DLR Falcon aircraft

The payload of the DLR Falcon aircraft will consist of the A2D and the 2-µm Doppler wind lidar DWL (Fig. 1) as for AC01/AC02. The following improvements and modifications on the A2D have been performed during the last airborne campaign AC02 compared to AC01:

- different pressure dependency of Mie and Rayleigh spectrometer (MSP, RSP) could be compensated by a 2.5 K lower temperature for the RSP and MSP than on ground, which compensates for a pressure difference of 115 hPa
- pressure inside the cabin was set on the start of the flight to a constant level and not changed manually by the pilots, when the flight level was changed (as during AC01); the variation of the pressure level was within +-2 hPa
- automatic co-alignment loop was operated; during the first 2 flights the triggering of the UV camera was not correct, which could not be observed with ground observations; the triggering of the UV camera was optimized before the flight on December 3; the co-alignment loop performance is about a factor of 4 better than during AC01, but still about a factor of 2-4 worse than on-ground
- the new wavemeter with autocalibration mode was operated during the flights as a pressure independent absolute frequency reference
- the A2D was operated by 2 operators during the flights with one operating the 2-µm in parallel.
- the laser ground cooler was operated for temperature stabilisation of laser and OBA on ground until short before aircraft engine ignition; this reduces the in-flight thermal stabilisation time to about 45 min.

The following improvements and modifications on the A2D will be performed for the next airborne campaign AC03:

- UV camera focus will be set from near ranges (1-2 km) to infinity (10 km); it is expected that the signal for the UV camera from the ground return is higher, which will be verified during the test flight
- improvement of the design of the 48 MHz clock signal for the DEU; this measure could prevent the sporadic failures of the DEU, which occurred during the flight on December 3, 2008
- automatic co-alignment loop does not operate when the aircraft is flying within a cloud layer or with a cloud layer in a distance of up to 1 km; thus the flight altitude must be adapted to fly below cirrus clouds or in regions with no cirrus clouds
- no useful Rayleigh winds were obtained on the first 2 km below the aircraft; thus the flight altitude will be as high as possible constrained by aircraft operations and cirrus cloud coverage; also the first 2 km will be sampled with coarse vertical resolution (e.g. 8.4 µs, 1260 m)

The A2D and the 2-µm will be mounted inside the aircraft cabin as during AC02 and pointing with their LOS perpendicular to the aircraft axis with an angle of 20° off nadir. The nominal operation of the 2-µm lidar will be the measurement of the LOS wind. Some conical step-stare scans will be performed in order to measure the horizontal wind vector during flight. Different off-nadir angles of both instruments, e.g. 3°, 20°, 30°, and 37.5° will be achieved by rolling the aircraft while flying curves. The vertical sampling of the A2D will be similar as during AC02, adapting for a higher range from aircraft to ground, when operating with 37.5° off nadir angles. The vertical sampling will be set such, that the ground layers are sampled with highest vertical resolution (2.1 µs, 315 m range). The same vertical sampling resolution will be chosen for Mie and Rayleigh receiver.

7.2 Instrumentation on the ground

During the test flight it is foreseen to fly over the windprofiler sites Lindenberg and Bayreuth (Fig. 3, Tab. 2), if weather conditions allow.

For the transfer flight from Oberpfaffenhofen to Keflavik and return, an overflight over the Cabauw experimental (RAMAN lidar CAELI, boundary layer winprofiler) and over de Bilt (radiosonde KNMI) could be foreseen (Fig. 2). The windprofiler sites in Wattisham, Aberystwhyth, Isle of Man, and South Uist could be used for intercomparison on the transfer flights (Fig. 3, Tab. 2). The windprofilers with frequency of 915 MHz and 1290 MHz in the UHF (ultra-high frequency) band are boundary layer profilers, which provide wind profiles up to 3-4 km typically (Wattisham, Isle of Man, Cabauw). The 482 MHz windprofilers (UHF) are used for tropospheric winds up to 12 km (Bayreuth, Ziegendorf, Lindenberg, Nordholz). The profilers operating at 40-65 MHz in the VHF (very-high frequency) band cam reach up to the stratosphere (South Uist, Aberystwyth). The actual availability of the profilers will be checked close to the campaign via a password protected access to the CWINDE network, where real-time data is available.

No ground sites with windprofilers are available in the region of Iceland and Greenland. Radiosondes are launched at 0 UTC and 12 UTC (2 and 14 Local Time) from Keflavik (Iceland) and sites in Greenland (Fig. 4, 5 and Tab. 3.).

Site	Location	Instruments	next radiosonde
Lindenberg, North Germany	52.21 °N (52° 12.6’) 14.13 °E (14° 7,8’) 107 m	482 MHz windprofiler (RASS), Raman lidar RAMSES, radiosonde	directly on site
Ziegendorf, North-Germany	53.31 °N (53° 18.6’) 11.84 °E (11° 50,4’) 55 m ASL	482 MHz windprofiler (RASS)	Greifswald (135 km), Bergen (140 km)
Nordholz, North-Germany	53.78 °N (53° 46.8’) 08.67 ° E (8° 40.2’) 18 m ASL	482 MHz windprofiler (RASS)	Schleswig (100 km), Emden (183 km)
Bayreuth, South-Germany	49.98 °N (49° 58.8’) 11.68 °E (11° 40,8’) 514 m ASL	482 MHz windprofiler (RASS)	Kuemmersbruck (63 km)
Leipzig, North-Germany	51.375 °N (51° 22.5’) 12.446 °E (12° 26.8’) 120 m ASL	Aerosol Raman lidar MARTHA at 355 nm, 532 nm, (1064 nm)	Lindenberg (151 km)
Cabauw, Netherlands	51.97 °N (51° 58.2’) 4.927 °E (4° 55.6’) -0.5 m ASL	1290 MHz windprofiler, RASS	de Bilt (30 km)
Bilthoven, Netherlands	52.121 °N (52° 7.234') 5.192 °E (5 °11.510')	RAMAN lidar CAELI 355 nm, 532 nm, 1064 nm	de Bilt (3 km)
Wattisham	52.7 °N 0.058°E 87 m	1290 MHz windprofiler	
Aberystwyth	52.4 °N 4.0 °W 50 m	46.5 MHz windprofiler, add. ground observations	
Isle of Man	54.06 °N 4.37 °W 55 m ASL	915 MHz windprofiler	
South Uist	57.353 °N 7.375 °W 4 m ASL	64 MHz windprofiler	

Tab. 2: Coordinates of ground sites for AC03 from CWINDE network and EARLINET network

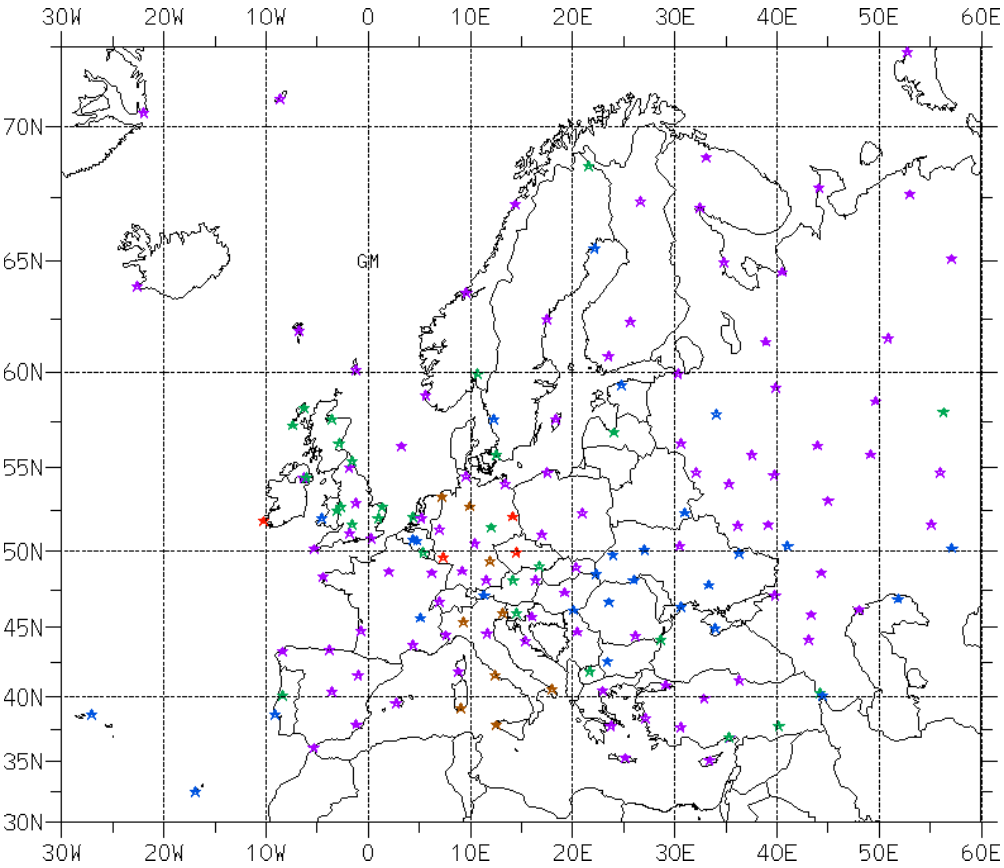

Fig. 4: Radiosonde network in Europe 2009 (http://www.uni-koeln.de/math-nat-fak/geomet/meteo/winfos/radiosonden/Europa/index_europa.html)

Fig. 5: Radiosonde network around Greenland and Iceland (http://weather.uwyo.edu/upperair/sounding.html)

Name	Identifier	WMO station nr.	Lat.	Long.	Elev.	Location
Transfer to Iceland						
Ekofisk	1400	1400	56.52 °	+3.22 °	52 m	North sea
Lerwick	3005	3005	60.13 °	-1.18 °	84 m	Shetland Islands
Thorshavn	6011	6011	62.02 °	-6.77 °	56 m	Faroer Islands
Iceland and Greenland						
Keflavik	BIKF	4018	63.96 °	-22.60 °	54 m	Iceland
Jan Mayen	ENJA	1001	70.93 °	- 8.66 °	9 m	north of Iceland
Ittoqqortoormiit	BGSC	4339	70.48 °	- 21.95 °	69 m	Greenland east coast, north
Tasiilaq, Ammassalik	BGAM	4360	65.50 °	- 37.63 °	52 m	Greenland east coast, central
Narsarsuaq	BGBW	4270	61.15 °	-45.43 °	5 m	Greenland east coast, south
Aasiaat, Egedesminde	BGEM	4220	68.70 °	-52.85 °	41 m	Greenland west coast, central

Tab. 3: Location of radiosonde stations for transfer to Iceland and at Iceland and Greenland.

The availability of the windprofilers under consideration for AC03 and their maximum vertical range was verified on 14/07/09 and 15/07/09 from the real-time displays:

- South Uist: wind up to 12 km
- Isle of Man: wind up to 5 km
- Aberystwyth: wind up to 15 km
- Wattisham: wind up to 5 km
- Cabauw: wind up to 5 km
- Nordholz: only low mode with wind up to 5 km available (permanent)
- Ziegendorf: wind up to 14 km
- Lindenberg: only low mode with wind up to 10 km available (due to tests)
- Bayreuth: only low mode with wind up to 8 km available (due to actual problems in high mode)

8 Implementation AC03

The aircraft will be based in Keflavik, Iceland. Integration of the A2D and 2-µm wind lidar will start on September 10, 2009. The Falcon is available until October 2, 2009.

Before the test flight an alignment of transmit-receive path is needed with atmospheric signal. This requires taking out the Falcon aircraft off the hangar and pointing the laser towards the atmosphere with a ground mirror for 2-3 hours. Preferably clear sky or few clouds without precipitation is needed for that. Thus the test flight could be earliest on September 16 in the afternoon after performing the atmospheric alignment. In case of unfavorable weather conditions for atmospheric alignment the test flight will be delayed to September 17 or 18. In case of unfavorable weather conditions for atmospheric alignment until September 18, a functional test flight will be performed without atmospheric signal on September 18.

Transfer from Oberpfaffenhofen to Iceland is foreseen on September 18 or 19. In case of good weather conditions the transfer will be performed via Netherlands and UK (option B). In case of no lidar operation on the transfer flight (e.g. due to clouds in flight level) the shortest route to Iceland will be chosen (option A). Transfer from Keflavik to Oberpfaffenhofen is planned for October 1or 2 (option A or B) and removal of the A2D and 2-µm wind lidar on October 2 or 5.

A total of 31 flight hours is available for AC03. It is foreseen a test flight with 3 hours and the duration of both transfer flights is estimated to be 8 h. This results in about 20 flight hours on-site in Iceland for about 5 flights.

A hangar for the Falcon aircraft is reserved at Keflavik International Airport (KEF). 3 offices and 1 storage room are reserved in a distance of 500 m to the hangar. It is planned to be with 11 persons on-site for the following duties: 2 pilots, 1 aircraft technician, 2 Falcon sensors operation and data analyses, 3 A2D operators, 1 2-µm operator, 1 weather forecast (tbc), 1 campaign coordination.

The equipment for the operation of the Falcon aircraft and the lidar instruments will be shipped to Iceland by sea container with pickup at DLR on August 28 and delivery in Keflavik on September 17. For the A2D a second ground cooler unit, processing computers, tools and a clean room tent will be shipped. For the 2-µm wind lidar several processing computers and storage discs will be shipped. After the test flight additional hardware for the A2D will be shipped to Iceland by aircargo, which takes between 3-4 days. This could limit the operation of the A2D in Icleand for the first 2-3 days.

Preferably a first atmospheric response calibration will be performed from ground with the Falcon aircraft outside of the hangar in Oberpfaffenhofen. The performance of this calibration is not a condition for the transfer flight. In any case it is planned to perform response calibrations from the ground in Keflavik.

8.1 Test Flight

Objective: Test Flight: functional test A2D operation in the aircraft, especially automatic co-alignment loop; verify atmospheric path alignment, verify Rayleigh spectrometer temperature setting to compensate for pressure change, test 2-µm DWL operation

Weather: clear sky, or broken clouds during some parts of the flight needed

Flight Level: 10-11 km (FL350)

Flight path:

1) Flight above windprofiler site Ziegendorf (53.31°N, 11.84°E) with straight leg of 100 km centered at windprofiler

2) Flight above windprofiler site Lindenberg (52.21°N, 14.13°E) with straight leg of 100 km centered at Lindenberg

3) Flight above aerosol lidar site in Leipzig (51.375 °N, 12.446 °E) with straight leg of 100 km centered at Leipzig

4) Flight above windprofiler site Bayreuth (49.98°N, 11.68°E) with straight leg of 100 km centered at windprofiler and back to Oberpfaffenhofen

Duration: 3 hours

Remarks: in case of clouds above Lindenberg and Bayreuth the test flight will be performed elsewhere

8.2 Transfer flight A

Objective: Transfer to Iceland on shortest route

Weather: transfer will be performed during all weather conditions

Flight Level: 11 km (FL350) depending on available aircraft routes

Duration: 4.5 hours

Flight path:

1) Towards Northern Germany possibly passing the windprofiler in Nordholz (53.78 °N, 8.67 °E)
2) Towards Shetland Islands, Faroer Islands and Kevlafik

Remarks: Fuel stop possibly needed; time of flight and routing is not depending on weather conditions

8.3 Transfer flight B

Objective: Transfer to Iceland via UK windprofiler sites for intercomparison

Weather: Transfer via UK only in case of clear sky or broken clouds over windprofiler sites

Flight Level: 11 km (FL350) depending on available routes

Duration: tbd

Flight path:

1) Towards Netherlands and flight over Cabauw, de Bilt
2) Flight above windprofiler sites in UK
    - 2.1) Wattisham (52.7 °N, 0.058 °E)
    - 2.2) Aberystwyth (52.4 °N, 4.0 °W)
    - 2.3) Isle of Man (54.06 °N, 3.37 °W)
    - 2.4) South Uist (57.353 °N, 7.375 °W)
3) Fuel stop
4) Transfer to Keflavik

Remarks: Fuel stop needed; option B for transfer will be performed if weather conditions are favorable, e.g. no clouds in flight level, no or broken clouds below

8.4 In-flight response calibration over Greenland

Objective: Obtain surface reflectance over ice and snow; perform in-flight response calibration over ice

Weather: no clouds during most parts of the flight needed

Flight Level: 10-11 km (FL350)

Duration: up to 6-8 hours with fuel stop in Kangerlussuaq

Flight path

1) Flight towards Greenland

2) Circles over Greenland for up to 1.5 hours (depending on flight duration to Kangerlussuaq) with roll angle of 20 ° (right curve), resulting in about 3 ° nadir angle

3) Flight towards Kangerlussuaq and fuel stop

4) Flight back to Keflavik on constant flight altitude to obtain surface reflectance over ice and snow in several range gates; possibly additional circles over Greenland as described in 2) and rolling the aircraft slowly by +- 20° for several times over ice

Remarks: The flight above Greenland should be performed around the radiosonde launch time of 12 UTC (14 Local Time); no alternate airport is available for Kangerlussuaq which requires a 1.5 h flight margin

8.5 Sea and land surface flight

Objective: Obtain dataset of sea surface reflectance for high wind speeds and surface reflectance over land

Weather: clear sky needed over sea, preferably performed during high surface wind conditions to complement dataset of AC02

Flight Level: 10-11 km (FL350) for transfer and 7-8 km (FL 250) over sea for circles

Duration: up to 4.5 hours

Flight path:

1) Flight towards target area, e.g. ocean between Iceland and Greenland

2) Flights above sea on lower flight level, e.g. 7-8 km (FL 250)

2.1) straight leg of 100 km

2.3) 2 circles with roll angle of 10° (right curve) resulting in about 10° nadir angle

2.2) 2 circles with roll angle of 20° (right curve), resulting in about 3° nadir angle

2.2) 2 circles with roll angle of -18° (left curve), resulting in about 38° nadir angle

2.3) 2 circles with roll angle of -10° (left curve) resulting in about 30° nadir angle

2.4) straight leg of 100 km in flight direction parallel to predicted sea surface wind direction

2.5) straight leg of 100 km in flight direction perpendicular to sea surface wind direction

3) Flight back to Iceland and flight above Iceland on 1 flight level

Remarks: The flight above the sea should be performed around the radiosonde launch time of 12 UTC (14 Local Time) and coordinated with an overpass of a satellite scatterometer, e.g. QuikSCAT or ASCAT.

8.6 Jet stream flight

Objective: Obtain wind measurements with high wind speeds and high vertical shear

Weather: no clouds in flight level, high wind speeds with high vertical shear in jet-stream region.

Flight Level: 10-11 km (FL350); below cirrus level

Duration: up to 4.5 hours

Flight path:

1) Flight towards target area with jet streams

2) Several straight flight legs of 100-200 km length within jet stream with aircraft heading perpendicular to wind direction and preferably horizontal gradient in wind speed within the straight leg.

3) 2 circles with roll angle of 20° (right curve), resulting in about 3° nadir angle

3) Flight back to Iceland

4) 2 circles with roll angle of 20° (right curve) over land

5) Flight back to Keflavik

Remarks: The flight within the jet stream should be performed around the radiosonde launch time of 12 UTC (14 Local Time).

8.7 Low pressure flight

Objective: Obtain wind and cloud coverage measurements over developing low-pressure system

Weather: no clouds in flight level, developing low-pressure system

Flight Level: 10-11 km (FL350); below cirrus level

Duration: up to 4.5 hours

Flight path:

1) Flight towards low-pressure system

2) Several straight flight legs of 100-200 km length above core of low-pressure system with with aircraft heading perpendicular to wind direction

3) Flight back to Iceland

4) 2 circles with roll angle of 20° (right curve) over land

5) Flight back to Keflavik

Remarks: The flight above the low pressure system should be performed around the radiosonde launch time of 12 UTC (14 Local Time).

8.8 Backup flight

4 fight patterns are defined in chapter 8.4 to 8.7 to match the objectives of the campaign. As 4-5 flights can be performed on-site in Iceland, additional flights could be performed, if flight hours on the Falcon aircraft remain. These flights will be similar or modified flight tracks, depending on the achieved objectives so far.